

## Unit 6 – The Nervous System

Pleasant Valley High School  
Anatomy and Physiology

### 9.1 Introduction

- ◊ Nerve Cells are called *neurons*
- ◊ You need to know all the parts of a neuron as seen in Figure 9.1
- ◊ Nervous cells are made of neurons and neuroglial cells (nerve glue)
- ◊ CNS – made of brain and spinal cord
- ◊ PNS – nerves that connect the CNS to the body parts

### 9.2 Functions of the Nervous System

- ◊ Sensory Function – collects information through sensory receptors that detect changes both internally and externally, then convert that info into impulses
- ◊ Integrative Function – when nerve impulses reach the CNS, they are converged to a useable signal
  - ◊ This creates memories and sensations that can be translated into perception

- ◊ We make either conscious or subconscious decisions to use motor functions and carry them out
- ◊ Effectors – the responsive structures that lie at the ends of peripheral neurons
  - ◊ These can be muscles or glands that secrete

## 2 Categories of Motor Functions

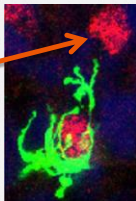
- Somatic Nervous System – actions that are consciously controlled, part of the peripheral nervous system that controls skeletal muscle
- Autonomic Nervous System – effectors that are involuntary such as the heart, smooth muscle in blood vessels, and various glands
- Nervous system helps to maintain homeostasis through the ANS by detecting imbalances and triggering changes

## 9.3 Neuroglial Cells

- Fill spaces
- Provide structural framework
- Produce myelin (covering of the axons)
- Carry out phagocytosis (self eating)
- Four types of neuroglial cells
  - Microglial cells
  - Oligodendrocytes
  - Astrocytes
  - Ependymal cells

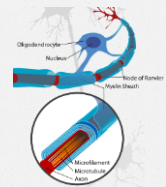
## Microglial Cells

- Scattered throughout the CNS
- Support neurons and phagocytize bacterial cells and cellular debris



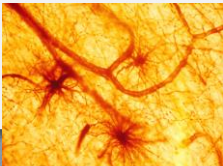
## Oligodendrocytes

- Occur in rows along nerve fibers
- Provide layers of insulating myelin around axons within the brain and spinal cord



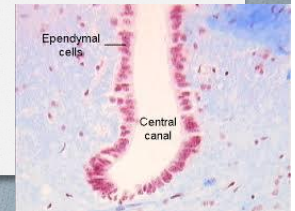
## Astrocytes

- Found between neurons and blood vessels
- Provide structural supports
- Join parts by cellular process
- Help regulate nutrient concentration
- Form scar tissue after injury to the CNS



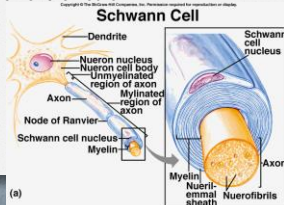
## Ependymal Cells

- Form an epithelial like membrane that covers brain parts and forms inner linings that enclose brain ventricles and the spinal cord



## Schwann Cells

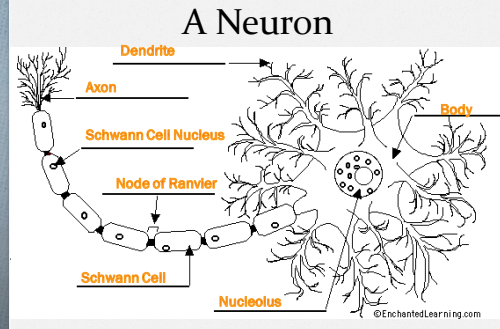
- Specialized neuroglial cells that produce myelin
- Myelin forms a sheath that surrounds the axon of the neuron



## 9.4 Neurons

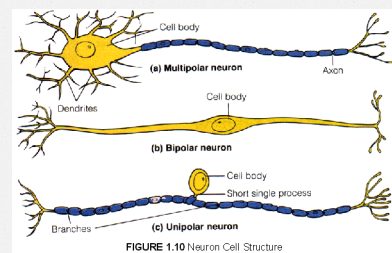
- Vary greatly in size and shape, but all have common features
  - Cell body, cytoplasm filled dendrite that conducts nerve impulses, and axons which conduct impulses away
- Neurofibrils – a network of fine threads within the body of the cell
  - These extend into the axons
- Chromatophilic Substance – membranous sacs scattered throughout the cytoplasm
  - Similar in appearance to rough ER
  - Called Nissl Bodies

- Dendrites are usually short and very highly branched
- Mature neurons DO NOT divide or reproduce
- Some parts of the NS include neural stem cells that can give rise to new neurons or neuroglia
- The axon arises from a slightly elevated section called the *axonal hillock*
- *Neurilemma* – the portions of the Schwann cells that are primarily cytoplasmic and surround the myelin sheath
- *Nodes of Ranvier* – thin gaps in the myelin sheath between Schwann cells



## Classification of Neurons

1. Bipolar Neurons
  1. Has only two processes, one arising from polar ends, one is an axon and the other a dendrite despite their near identical appearance. Found in specialized parts of the eyes, nose and ears
2. Unipolar Neurons
  1. Single process extending from a cell body, this process divides into two branches which function as a single axon. One branch enters the PNS and the other the CNS. Cell bodies of unipoles aggregate into masses of nervous tissue called ganglia and are found outside the brain and spinal cord
3. Multipolar Neurons
  1. Many processes arising from the body, only one process is an axon and the remainder are dendrites. Most neurons in the brain and spinal cord are multipoles



- On the basis of functional differences, neurons are grouped as:
  - Sensory Neurons – afferent, carry impulses from the PNS to the CNS, unipolar and bipolar
  - Interneurons – association, entirely within the CNS, multipolar
  - Motor Neurons – efferent, carry impulses from the CNS to the PNS, responsible for muscle stimulation and glandular release
- See Figure 9.6

## 9.5 Cell Membrane Potential

- Potassium ions move easily through the membrane and cause polarization of the membrane
- *Resting Potential* – potassium diffuses out of the cell faster than sodium can diffuse into the cell. As a result the outside of the cell becomes slightly positive and the inside is slightly negative.
  - This difference in electrical charge is called *potential difference*
  - As long as a nerve cell remains undisturbed, this polarized state remains

- *Depolarization* – if the membrane's resting potential decreases (inside is less negative than the outside), it depolarizes
- *Summation* – the addition of necessary charges to reach resting potential again
  - Once the potential reaches a certain point, it is considered to be at **threshold potential**.
  - Threshold potential initiates an event called *action potential*

- **Action Potential**
  - Sodium channels open and allow sodium to enter the cell
  - This movement and the negative charges already in the cell attract the positive sodium ions
  - This influx causes the cell to lose its negative charge and become resting again
  - Membrane channels can also allow Potassium to flow in as needed
  - This action re-polarizes the cell
  - This process takes less than 1/1000 of a second

## 9.6 Nerve Impulse

- The propagation of action potentials along a nerve axon
- An unmyelinated nerve conducts an impulse along its entire axon surface due to there being no insulation
- A myelinated nerve only conducts an impulse in the nodes of Ranvier
  - The impulse jumps from one node to the next and is much faster than the impulse of an unmyelinated nerve
  - The greater the nerve diameter, the faster the impulse travels
  - All-or-nothing response just as in muscles

## 9.7 The Synapse

- The junction between two communicating neurons
- Synaptic cleft – the physical space between two neurons in which the impulse jumps
- Synaptic Transmission Order
  - Presynaptic neuron dendrite → axon (with synaptic knobs) → synaptic cleft → dendrite of postsynaptic neuron

- Neurotransmitters are located in synaptic vesicles in the knobs of the axons
- Excitatory and Inhibitory Actions
  - Excitatory – neurotransmitters increase postsynaptic permeability to sodium ions
  - Inhibitory – decrease the permeability to sodium ions and lessen a chance that the action threshold will be met
  - One dendrite may have thousands of knobs releasing different actions, that's why you only get a sensation at the site of the stimulus

## Neurotransmitters

- Acetylcholine – skeletal muscle contractions
- Monoamines – epinephrine, norepinephrine, dopamine, and serotonin
- Several amino acids (glycine, glutamic acid, aspartic acid, GABA)
- Neuropeptides – short chains of amino acids
- Acetylcholine and norepinephrine are excitatory
- Dopamine, GABA, and glycine are inhibitory
- Acetylcholinesterase and monoamine oxidase break down neurotransmitters and stop nerve impulse
  - These are enzymes found in the synaptic cleft and/or the synaptic knob



## 9.8 Impulse Processing

- Neuronal Pools – groups of neurons within the CNS that work together to function
- *Facilitation* – when neurons within a pool receive inhibitory and excitatory input, the net effect may be excitatory, but sub-threshold and leave the neurons excitable
- *Convergence* – makes it possible for a neuron to receive stimuli from different axons. It allows the CNS to receive info from throughout the body and react to it.

- *Divergence* – when neurons leaving a pool split up into several output neurons. This amplifies the effect of an impulse
- *Can result in forceful contraction of skeletal muscle*
- *Similarly, if a person smells a familiar scent, they might also taste the scent...multiple neuronal pools being stimulated...*

## 9.9 Types of Nerves

- Sensory (afferent) – send information into the CNS
- Motor (efferent) – send info to the PNS and conducts muscles and glands
- Mixed – a combination of function for sensory and motor

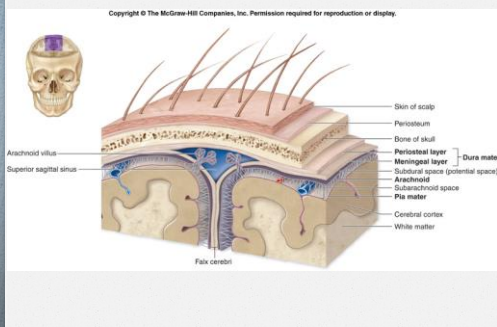
## 9.10 Nerve Pathways

- Reflex Arc – begins with a receptor at the end of a sensory fiber, leads to interneurons in the CNS, simplest of all nerve pathways
- Reflexes – automatic and subconscious responses to changes within or from outside the body, used to maintain homeostasis
  - Heart rate, breathing rate, blood pressure
  - Knee-jerk reflex (patellar tendon reflex) – ensures you stay standing when attempting to do so
  - Withdrawal reflex – occurs when you touch a hot stove or anything that causes pain

## Nervous System Anatomy

### 9.11 Meninges

- Membranes that help protect the brain and spinal cord
- Three layers
  - Dura Mater – “tough mother”, outer layer, tough fibrous CT
  - Arachnoid Mater – thin, web-like membrane that lacks blood vessels, located between the dura and pia maters
  - Between the arachnoid and pia mater is a layer of cerebrospinal fluid
  - Pia Mater – very thin, contains many vessels and nerves, hugs the contours of the surface of the brain and spinal cord, “soft mother”



### 9.12 The Spinal Cord

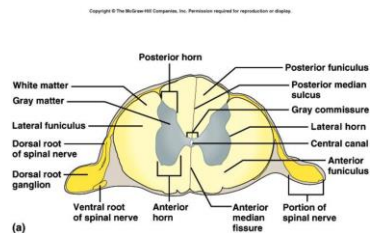
- 31 segments that each give rise to a pair of spinal nerves (connect body parts to the CNS)
- Cervical Enlargement – nerves to the neck and upper limbs
- Lumbar Enlargement – nerves to the lower limbs
- Anterior Median Fissure – deep groove
- Posterior Median Sulcus – shallow groove



- Contains a core of gray matter surrounded by white matter all around a central canal
- Anterior and Posterior horns of gray matter
- Lateral horn of gray matter extends to the sides
- Anterior Horns – contain nerve with large cell bodies that deliver impulses to skeletal muscles

- White Matter is divided into three regions by the gray matter
  - Anterior, Posterior, and lateral funiculi
  - Each one comprises major nerve pathways and tracts
- Gray Commissure – horizontal band of gray matter that surrounds the central canal

## Cross Section of Spinal Cord



11-7

## Functions of the Spinal Cord

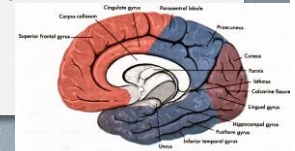
- Conducting nerve impulse
- Serves as a center for spinal reflexes
  - Knee jerk and withdrawal are spinal reflexes as their reflex arcs pass through the spinal cord
- Ascending Tracts – carry sensory info to the brain
  - Axons extend from the Spinal cord to the toes...when you stub your toe, it takes less than 1/1000<sup>th</sup> of a second for the ascending tract to complete
- Descending Tracts – carry motor impulses from the CNS to the peripherals

## 9.13 The Brain

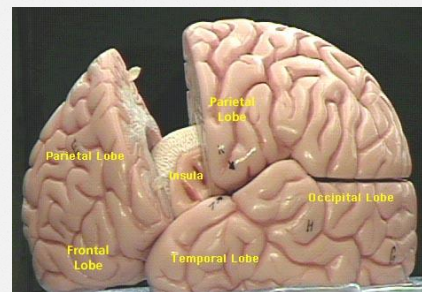
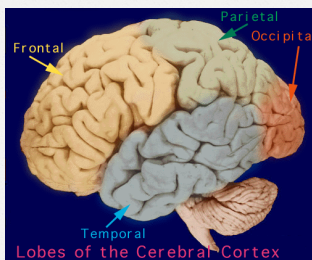
- Made of about 100 billion multipolar neurons and even more nerve fibers that allow communication of these neurons and those in other parts of the NS
- Three major portions:
  - Cerebrum – largest portion, nerves for sensory function and motor, memory and reasoning
  - Diencephalon – sensory info, **not a major portion**
  - Cerebellum – voluntary muscle movements
  - \*\*Brain Stem\*\* - connects parts of the CNS and manages visceral functions

## Cerebrum

- Right and left cerebral hemispheres connected by the corpus callosum
- Surface has ridges (*convolutions*) called *gyri* separated by grooves
- *Sulcus* – a shallow groove
- *Fissure* – a deep groove



## Lobes of the Cerebrum



- Below the cerebral cortex is a bulk of white matter
- Mass contains bundles of myelinated axons that connect neurons of the cortex with other parts of the NS

## Functions of the Cerebrum

- Higher order thought
- Memory
- Reasoning
- Intelligence
- Personality
- Motor function – frontal lobe
- Motor speech (Broca's area)
- Frontal eye field
- Sensory areas
- Skin senses, auditory, visual

- Association Areas – either sensory or motor
- Analyze and interpret sensory info
- Oversee memory, reasoning, verbalizing, judgment and emotion
- General interpretive area – complex thought processing

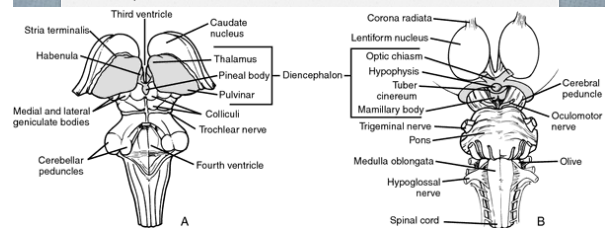
## Ventricles and Cerebrospinal Fluid

- Ventricles – interconnected cavities within the cerebral hemispheres and the spinal cord that contain cerebrospinal fluid
- Choroid Plexuses – specialized capillaries from the pia mater that secrete CSF
- CSF provides support and protection to the brain and spinal cord. It maintains a stable ionic balance in the CNS and carries waste to the blood

## Diencephalon

- Composed of primarily gray matter
- Made of:
  - Thalamus – relay for sensory info (pain, touch, temp.)
  - Hypothalamus – homeostasis
  - Optic tracts and optical chiasma
  - Infundibulum – conical shaped process
  - Posterior pituitary gland – hangs from the floor of the hypothalamus (part of the endocrine system)
  - Mammillary bodies
  - Pineal Gland – cone shaped structure at the top of the diencephalon

- Limbic System – controls emotions
- Uses fear, anger, and pleasure to influence a person's behavior

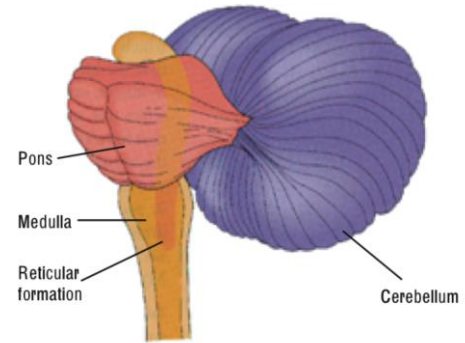


## Brain Stem

- Connects the cerebrum to the spinal cord
- Midbrain – short section of the stem. Myelinated axons join lower parts of the stem and spinal cord to the higher parts of the brain
- Visual reflexes and auditory reflex centers
- Pons – separates the midbrain from the medulla oblongata (its not why the alligator was mad), transmits impulses from the cerebrum to the cerebellum

- Medulla Oblongata
  - From the pons to the foramen magnum
  - 3 visceral centers in the medulla oblongata
    - Cardiac Center
      - Maintains heart rate
    - Vasomotor Center
      - Stimulate contraction of blood vessels and elevates blood pressure
    - Respiratory Center
      - Regulates rate of breathing

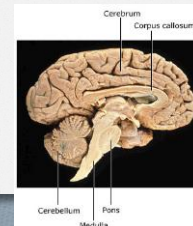
- Reticular Formation –
  - Upper portion of the spinal cord to the diencephalon
  - It activates the cerebral cortex into a state of wakefulness
  - If it gets injured, the body lies in a comatose state



## The Cerebellum

- Below the cerebrum and is posterior to the pons and medulla oblongata
- Primary function is dealing with posture and movement of limbs
- Communicates with the rest of the CNS through cerebellar peduncles
  - Inferior Peduncles – sensory info about actual position of limbs
  - Middle Peduncles – info about desired position of limbs
  - Superior Peduncles – instructions to move body parts

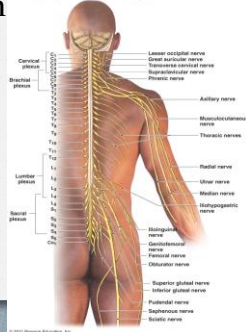
- Reflex center for integrating sensory information about the position of the body and complex skeletal movements



## 9.14 Peripheral Nervous System

The cervical, brachial, lumbar, and sacral plexuses (at left), and the major peripheral nerves of each (at right).

- Cranial and spinal nerves
- Two divisions
  - Somatic
    - Conscious activity
  - Autonomic
    - Subconscious activity



## Cranial Nerves – 12 Pairs

- Olfactory – S – smell
- Optic – S – vision
- Oculomotor – Mixed – muscles of the eye
- Trochlear – M – muscles of the eye
- Trigeminal – M – sensory info from the face and mouth
- Abducens – M – muscles that move the eyes

- Facial – M – taste receptors, facial expressions, tear glands, salivation
- Vestibulochlear – S – Equilibrium
- Glossopharyngeal – M
  - S – pharynx, tonsils, posterior tongue, carotid
  - M – pharynx, swallowing and salivation

- Vagus – M – muscles of speech and swallowing, heart, smooth muscle, glands of the thorax and abdomen
- Accessory – M – muscles of the soft palate, pharynx, larynx, muscles of the head and neck
- Hypoglossal – M – muscles that move the tongue

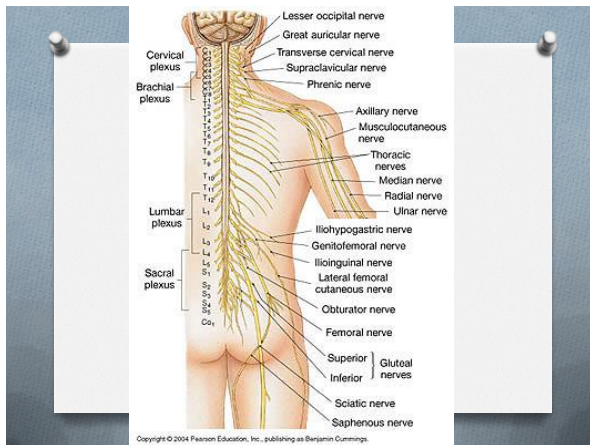


## Spinal Nerves

- Cervical – 8 pairs
  - Thoracic – 12 Pairs
  - Lumbar – 5 pairs
  - Sacral – 5 pairs
  - Coccygeal – 1 pair
- Lumbar, Sacral, and Coccygeal form the *cauda equina*, a bundle of nerves, known commonly as the horse tail
- Dorsal Root – conduct impulses into the CNS
  - Ventral Root – motor neurons whose cell bodies are within gray matter of the spinal cord

## Plexuses

- With the exception of thoracic nerves, all spinal nerve layers make up a complex network of nerves called *plexuses*
- Cervical Plexus – muscles and skin of the neck
- Brachial Plexus – 4 lower cervical nerves and 1<sup>st</sup> thoracic nerve, skin and muscles of the arms
- Lumbrosacral Plexus – nerves that extend from the lumbar region into the pelvic cavity



## 9.15 Autonomic Nervous System

- Functions completely independently
- This applies to all smooth muscle and cardiac muscle
- ANS is split into two branches
  - Sympathetic Division
    - Prepares body for energy to be spent during stress
  - Parasympathetic Division
    - Active during rest, counteracts the sympathetic

## ANS Nerve Fibers

- Preganglionic Fiber
  - Leaves the CNS and synapses with an autonomic ganglion
- Postganglionic Fiber
  - Extends to a visceral effector
- Cholinergic Fibers
  - Secretes acetylcholine
- Adrenergic Fibers
  - Secrete norepinephrine

## The Exam

- Know the parts of the Brain, Spinal Cord, ANS, CNS, PNS
- Know the types of nerves
- Know the functions of neurotransmitters
- Know nerve pathways

